Refrigeration Principles

An Online Continuing Education Course for Engineers

Course Number: HV-3013

Credit: 3 Hours / 3 PDH / 3 CPD

Refrigeration Principles

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INTRODUCTION

This course covers the fundamentals and the principles of the single compression refrigeration cycle. It includes the thermodynamic properties of the refrigerants and basic calculations used to determine capacities of each one of the refrigeration components in the single stage refrigeration cycle.

The objectives of the course are indicated in the previous section of the course.

This course requires basic knowledge of thermodynamics to understand the Pressure to Enthalpy diagrams and energy conservation equations. Most of the calculations needed will be based on these principles.

The course is divided into several sections to study each one of the basic components of the refrigeration cycle:

- compressor,
- condenser,
- expansion valve and
- evaporator.

At the end of the course, a section is included to cover the complete refrigeration cycle. The purpose of this last section is to show the student how some changes in one of the components can affect the overall performance of the complete cycle. Most refrigeration manufacturers provide refrigeration capacities for a specific unit based on outside conditions. This course will explain how changing those conditions can actually affect the overall performance of a given system.

The last section is probably the most important section because it ties all together in a system. The individual sections are designed to understand what happens to the refrigerant as it goes through each one of the them. Also, each component is selected individually to form the whole system, but it is very important to understand how variations in any of the components (or overall conditions) can affect the overall performance of the complete system.

Even though there are many types of refrigerants used, for the purpose of simplicity and consistency throughout the course, only ammonia (NH_3) (Refrigerant 717) properties and English system units are used in the course. However, the concept and calculation procedures would be **identical** if other refrigerants or units were to be used.

REFRIGERATION CYCLE

Heat transfer normally is conducted from an area of higher temperature to an area of lower temperature. This is the normal process of heat transfer. In contrast, refrigeration is a thermodynamic process where heat is transferred from a cold area to a warm area using mechanical or electrical work. The figure 1 illustrates a schematic diagram of a simple and single refrigeration compression system. The four essentials parts of the system are: compression, condensation, expansion and evaporation. These are the different steps through which the refrigerant needs to go through to absorb heat (at the evaporator) at a lower temperature and dissipate the heat (at the condenser) at a higher temperature.

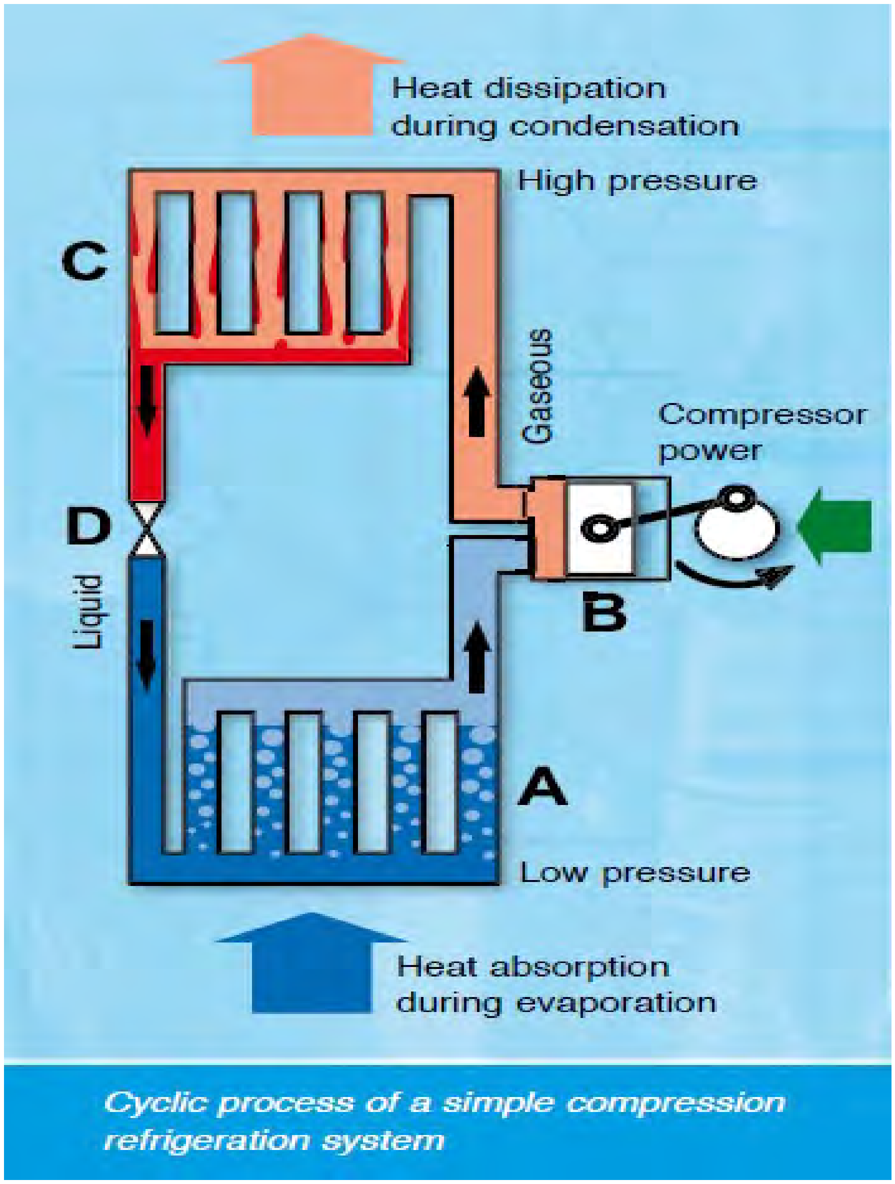

Fig. 1 Refrigeration system schematic.

There are several types of refrigeration used today: Electric, Compression cycle, Absorption cycle, etc. This course will concentrate only on the Single Compression Cycle as illustrated in the figure above. This is the operation of basic small air conditioners and typical refrigerator units.

The refrigeration process is a **closed cycle** (which means that the refrigerant neither leaves nor enters the system at any time in the process, it just recirculates). A specific amount of refrigerant gas is added into the system to work and unless there is a loss of the refrigerant over time (due to leaks in the system), there is no need to add any more.

The refrigerant goes through a series of steps (as mentioned above) in which it experiences changes of state (gas / liquid / gas) as it goes through the cycle. As the refrigerant goes through those steps, heat and/or work is absorbed or rejected. The final objective and result is to absorb heat from the evaporator (cold area) and exhaust it in the condenser (hot area). The refrigerant follows the path of the arrows in the diagram above.

The simplest refrigeration cycle is the single-stage compression cycle and is typical of most residential and small commercial air conditioners as well as typical appliances as mentioned above.

Refrigeration cycles are typically represented by a pressure-enthalpy diagram. Because the refrigeration cycle is a process where the refrigerant changes phases as it goes around the cycle, the pressure-enthalpy diagram covers the liquid phase, vapor phase and the liquid/vapor phase areas. A graphic diagram of the cycle is illustrated in Fig. 2 showing a pressure/enthalpy diagram. This diagram shows each one of the points at which the refrigerant leaves one component and enters the next one.

The basic process of the refrigeration cycle is as follows:

A) The cooling takes place in the evaporator. The evaporation process occurs at low pressures and low temperatures. Here the refrigerant absorbs heat from the environment around it, and cools the environment. When the refrigerant absorbs the heat from the environment, this heat will cause the refrigerant (which is liquid when it gets into the evaporator) to change phase from liquid to gas. Point 1 in figure 2.

B) The still cold refrigerant gas now, is aspirated by the compressor and compressed to a higher pressure and consequently higher temperature (in most cases) by using mechanical energy (compressor). Here the refrigerant gas heats up (remaining as gas) due to the compression process. This process is illustrated as the refrigerant goes from point 1 to point 2 in figure 2 below.

C) The hot refrigerant gas from the compressor now goes into the condenser which by using either cooling water or atmospheric air, is cooled down to the point of condensation. Here the hot refrigerant gas from the compressor is transformed into cool high-pressure liquid refrigerant. In order to do that, it needs to give up energy. This process is illustrated as the refrigerant goes from point 2 to point 3 in figure 2 below.

D) The high pressure cooled liquid refrigerant, from the condenser now goes to the expanding valve, where when it passes through it, it turns into a low-pressure liquid (sometimes, depending on the conditions of the refrigerant, some small amount of gas is formed) at a lower temperature. Now the refrigerant is ready to enter the evaporator and complete the cycle. This process is illustrated as the refrigerant goes from point 3 to point 4 in figure 2 below.

E) The cycle is repeated and is closed (remember, no refrigerant comes into the cycle or leaves the cycle).

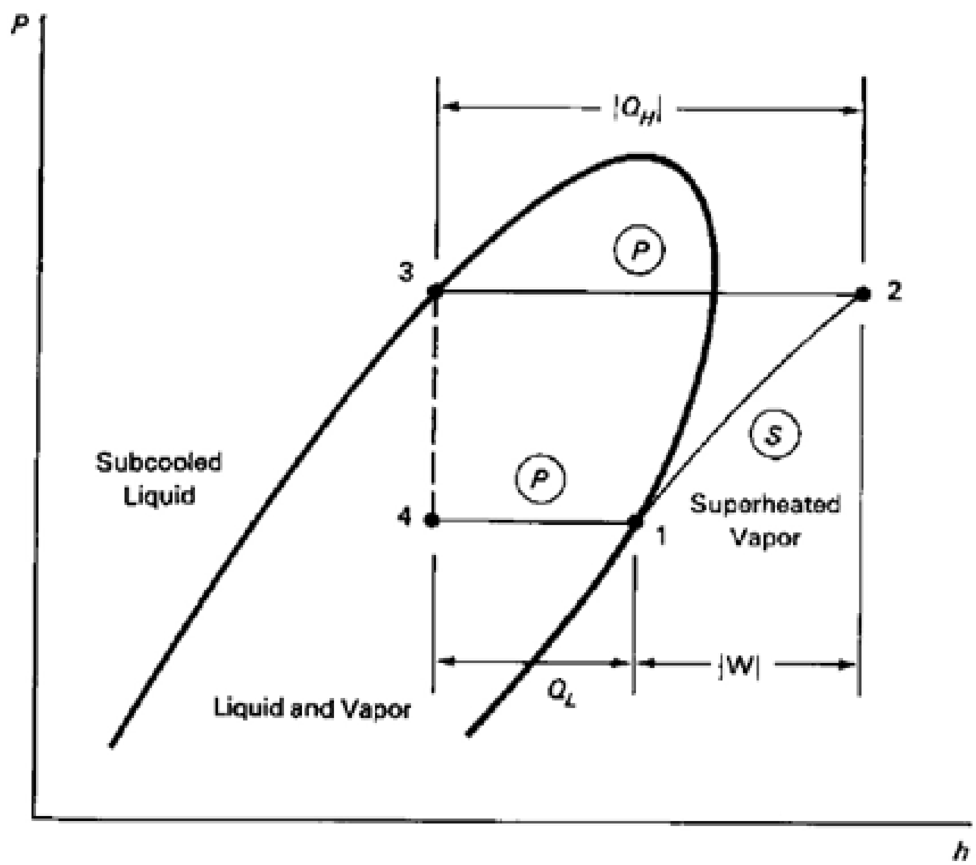

Figure 2. Pressure-Enthalpy diagram for refrigerant

The diagram shows the basic areas of the refrigerant (liquid, gas and liquid + gas) under different color. This is illustrated in figure 4 showing the basic areas of the diagram.

Most refrigerant diagrams represent the Pressure-Enthalpy diagrams as a log Pressure-Enthalpy diagram because of the large scale on the pressure side. A simplistic view of this diagram is shown in fig. 3 below.

In the center section of the graph (blue) it is shown the wet steam area. Here the temperature corresponds to the boiling temperature for the given pr… …et steam area is surrounded by the limit curves wit… … These lines indicate the amount of steam … …steam (gas) is 0.0% or 100 percent is liquid. … …% and the amount of liquid is 0.0 %. The oth… … the x lines.

The grey area of the ref… … the right is the steam area. The points along t… …g the liquid line is known as saturated liqu…

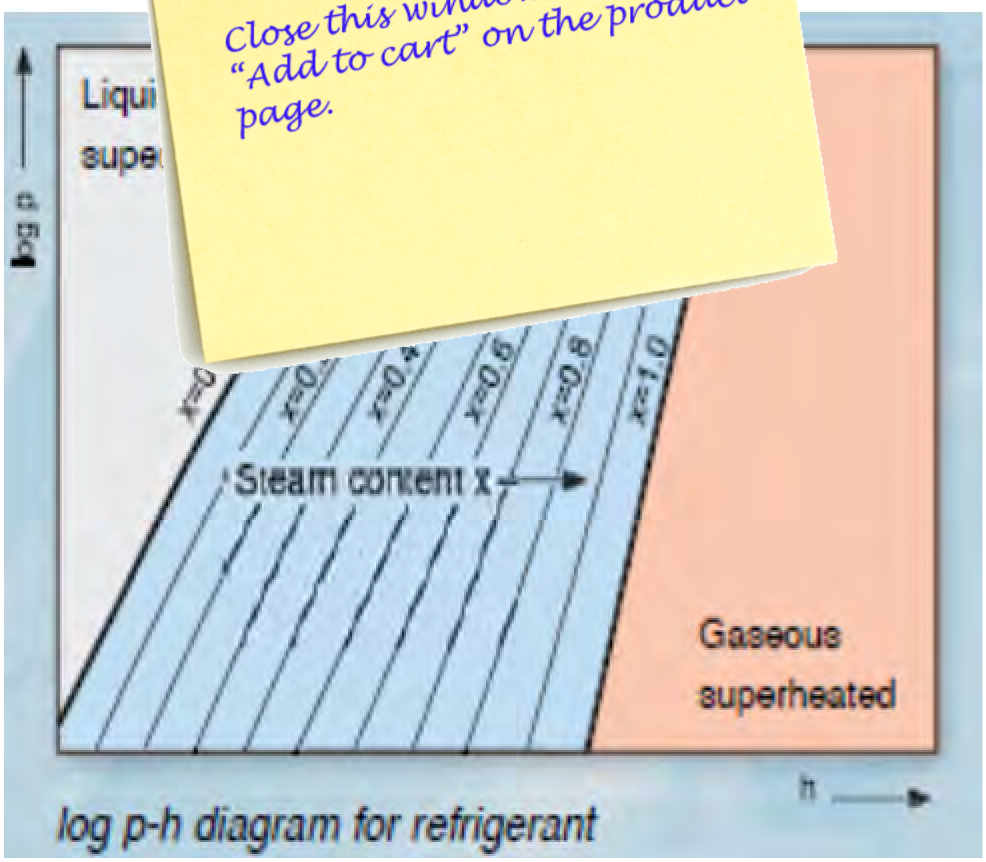

Fig. 3. Log Pressure – Enthalpy sketch diagram